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Keeping a Pact

As personal protective equipment for the battlefield improves, fewer troops are suffering fatal injuries. In past wars, 30 percent of injured Soldiers died from their wounds. Today, that number is 10 percent. This is largely because of the work of DARPA and others in developing technologies that can stop rounds from the most powerful firearms in the world.

But saving lives does not mean being able to totally protect our troops from harm. Young warfighters are returning from theater severely injured.

Alive—not unharmed. They are facing a threat far different from the enemies of the past. We are fighting against an insurgency, against enemies so set on violence that they resort to creating weapons that do the most violence possible, without regard to the consequences. They fill bags with glass, carpet tacks, rusty washers and ball bearings, and detonate them outside of voting booths, hospitals, mosques, temples, and schools. We fight an enemy without regard for human life, human potential, or human decency.

As a result, although our warfighters suffer fewer fatalities, they still suffer horrible injuries. And today one of the most devastating battlefield injuries is loss of a limb.

At DARPA, we have the vision of a future where a Soldier who has lost an extremity in battle will regain full use of that limb. If they could throw a baseball before, they will throw a baseball again. If they could play the piano before, they will play the piano again. And we will do it, we will get to this point, this future, by making revolutionary, neurally-controlled prosthetics.

Our warfighters wake up every morning to protect and serve American ideals in the face of the enemy because that is their duty and their desire. That is the pact they made to our country and they are fulfilling it proudly.

At DARPA, we have a pact with these men and women. We have pledged to develop revolutionary technologies that make them the best equipped fighting force in the world. We are also pledged to

making sure they return to their families as they were when they left: fully functional.

We have long been fulfilling our first pledge. Now we are also making excellent progress on the second.

Soldiers who have lost their legs are faced with a problem that has been examined and reexamined. The modern prosthetic leg is a robust device that allows a Soldier to return to almost full capacity. While no mechanical devices have yet been developed that are as efficient as biology, the basic biological functions of a leg can



Aftermath of a car bomb attack by insurgents in Iraq

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be accurately mimicked. The leg has relatively few joints to accomplish a primary function—locomotion. While much of the power of walking is provided, mechanically, by the ankle, the body can learn to adapt gait to compensate for that loss.

There are prosthetic legs with computers in the knees, C-Legs. These legs allow the user to alter the way they walk depending on the surface they're walking on. They can actively control the amount of resistance the knee gives. An amputee walking with a C-leg has a normal gait and stride, to the point where it would be nearly impossible to pick out an amputee in a crowd.

A South African man plans on running in the Beijing Olympics on his prosthetic legs. The time he's posted in the 400 meter nearly qualifies him for doing so. This man has lost both legs below the knee. He's not letting that limit him.

Soldiers who have lost their leg are qualifying for jump duty again. These Soldiers have suffered injuries while in combat and on duty in theater so traumatic they required amputation. After a few months of physical therapy and rehabilitation, after finding a leg that fits properly and can weather sand and grit and rain, they fully requalify as US Army paratroopers—Airborne.

The upper extremity, in comparison with the leg, is significantly more complicated. It delivers the most complex tool known to biology, the human hand. The upper extremity has 21 actuators that power it, tendons and muscle. It moves in a myriad ways: rotation at the shoulder and wrist, flexion and extension at the wrist, shoulder, and elbow. This is all to deliver the hand to its destination. The hand with its five fingers allows us to do all things human, from picking up a grain of sand to holding a bowling ball, writing poetry to driving a steam roller and, of course, playing the piano.

The best prosthetic arms available right now are powered by gross muscle movements or muscle constrictions. The most functional hand is a “work hand,” little different from a hook. The most

functional prosthetic shoulder does not allow you to reach behind your head. The most functional prosthetic wrist can rotate, but not flex or extend.

Our Soldiers need better. DARPA has undertaken the monumental task of fulfilling our pact to our Soldiers by embarking on an effort to provide fully integrated limb replacements that enable victims of upper body limb loss to perform arm and hand tasks with strength and dexterity of the natural limb.

Clearly, this is a DARPA-hard challenge. Breakthroughs in actuation, mechanical power distribution, energy storage, biotic/abiotic interfaces, sensors, and computation will be required. But the most important aspect of making this dream come true—what makes a “tool” a “limb”—is the ability to control the arm and hand by the intent of the user. Then, one could pick up a pen by thinking about it, or eat soup, or dial a phone. Over time, the brain has learned hundreds of thousands of sequences of component movements necessary for day-to-day living. The modern user of a prosthetic arm doesn't have a portable super-computer at their disposal to run complex control algorithms. Even if they did, the nature of computer programming would limit the ability of the prosthetic user to adapt to new situations.



DARPA's program vision for Revolutionizing Prosthetics is to restore function to amputees.

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Thanks to basic research led in large part by DARPA, we are beginning to unlock the mysteries of the brain. We are beginning to understand how the brain orders and structures commands for motion and feeling. Researchers have shown that monkeys can manipulate a robotic arm using only their thoughts. In the past few years, scientists demonstrated that an animal can be made to feel as though one of its limbs is being touched by directly stimulating the brain. Limited testing in humans shows similar promise. Thus, we firmly believe it will be through neural control, much like we now use to control our own motor activities, that we will revolutionize prosthetics.

We shouldn't downplay the mechanical aspects of this effort. The human arm and hand are extremely complex "machines." To be successful, we need parts to build this arm that mimic the sublime components provided us through millennia of evolutionary development.

There are few motors that work with the efficiency of tendon and muscle. In addition, prosthetic arms that are run by interlocking gears utilize more energy to replicate the types of work performed by biological actuators. We'll need new ways of converting energy into work to come close to the abilities of biology.

Over the course of a day, the body uses 1680 watts doing nothing but sustaining basic functions. The best batteries provide 200 watts. Over the course of a day, we would consume 8.5 kilograms of lithium-ion batteries just sustaining life. Biological

processes can provide an equivalent amount of power from less than a one-fifth of a kilogram of olive oil.

Bringing the complexities of biology into the world of engineering is a DARPA-hard problem. Through the combination of neural control and advances in power, sensing and actuation, we are going to bring prosthetics into a new, DARPA future.

Our Soldiers aren't just Soldiers. They're mothers and fathers. They're musicians and athletes. Let's give them an arm so they can play the piano. Let's give them an arm so they can throw a curveball or know what it feels like to hold their child's hand.

We're being very aggressive in our approach to this because we know it can be done. This is not a far-off dream; this is tomorrow's technology applied today. In 4 years, we anticipate having a prosthetic arm that will be controlled identically to the way that we control our biological arms. In 4 years, we intend on having an arm. The packaging for the Advanced Prosthetic will not include the sentence "some assembly required."

This program shows Americans that dreams can be realized and promises are kept. We will do whatever is necessary to restore these people who have given up so much for the idea of freedom. We will keep our promises. We will keep our end of the pact.